INERTIAL CONFINEMENT FUSION
Lawrence Livermore National Laboratory
Livermore, CA

Bimonthly Update

January-February 2005

UCRL-BR-144675-05-01

Ignition Target Designs for NIF

Ignition target designs for NIF require the formation of a smooth layer of deuterium-tritium (DT) fuel frozen on the interior surface of a spherical capsule made of plastic (CH) or beryllium. The indirect-drive (ID) approach to fusion being developed for NIF requires that this shell be centered in a cylindrical hohlraum that is used to generate the x-ray drive that implodes the capsule. A schematic of this target is shown in the March-April 2004 Bimonthly Update.[1]

We have recently demonstrate key steps needed to successfully field these targets on NIF: (1) controlled filling of a capsule with DT fuel through a 5-μm ID fill tube; (2) the formation of a DT ice layer that meets the NIF ignition smoothness requirement at high modes; and (3) partial control of low-mode ice layer roughness in a hohlraum.

The filling method utilizes a micron-scale fill-tube attached to the capsule and a low-pressure fill reservoir, as described above.[1] We have now successfully extended this method to DT fills. Figure 1 shows liquid DT sitting at the bottom of a transparent CH shell after filling. The hohlraum is vertical and gravity is directed downward. The shell is back-illuminated and imaged through a pair of diagnostic side windows added to the hohlraum for this measurement. The fill tube is located at about 9 o'clock in the image. When the reservoir is heated to ~50 K and the capsule cooled to ~20 K, the DT fuel flows from the reservoir, through the fill-tube and into the capsule, condensing in the bottom. Small temperature adjustments on the fuel reservoir allow us to easily control the DT liquid volume to high precision.

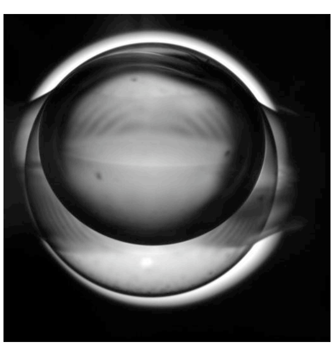


Figure 1. Target capsule view from diagnostic side window. It is filled with liquid DT, and the ice crystal seed is visible on top.

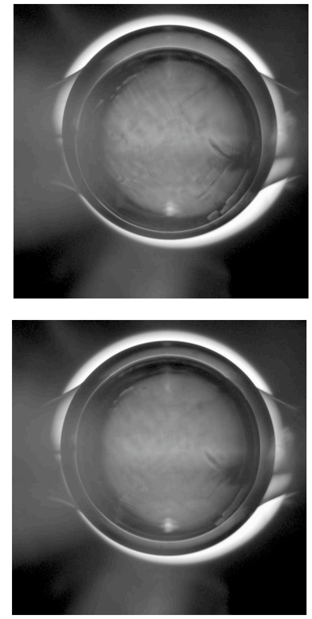
Layer Formation and Thermal Shimming

To form a smooth DT layer, we freeze and melt the fuel in the capsule until we obtain a single ice crystal seed from which we slowly grow the frozen fuel layer. Forming this single ice crystal is aided by generating a large axial temperature gradient in the hohlraum using heaters built into the hohlraum (these are called temperature shimming heaters), which allows control over the hohlraum thermal field. The roughness of the ice surface is characterized by the amplitude of modes where each mode is the number of oscillations of the ice layer that fit into its circumference.

The thermal gradient forces the initial freeze front to develop on the top of the capsule, where the liquid layer is very thin, and the crystal growth is more easily observable and controllable. Growing the fuel layer slowly from the liquid ensures a much smoother ice layer surface than is obtained when the liquid is rapidly frozen. The thermal gradient established to help grow the seed ice crystal produces a large offset in the solid layer as shown in Figure 2a. Removing the thermal gradient established for growing the ice layer causes the layer to become centered as shown in Figure 2b, demonstrating partial control of low-mode defects in the ice profile.

Separate experiments to demonstrate high-mode smoothness via beta-layering in a Be shell outside of a hohlraum have shown ice roughness that meets the specifications for the NIF ignition design at high modes (>7). Beta-layering refers to the ice redistribution process that results from self-heating of the DT ice due to beta emission from radioactive decay of tritium. Figure 3 shows a power spectrum obtained from a DT ice layer in a Be shell measured using phase contrast x-ray imaging.[2] Modes above 7 meet the NIF design requirement.

We have successfully demonstrated filling, layering, and the initial steps of thermal shimming to control low modes. Measurements outside of a hohlraum show that beta-layering produces an ice roughness that meets NIF requirements for modes above 7. Future effort will focus on reducing the amplitude of the few remaining modes in a NIF hohlraum, which have not yet been demonstrated to meet specifications.



(a)

(b)

Figure 2(a). Solid ice layer grown with large offset introduced by the seed crystal axial gradient. (b) Temperature shimming removes the large axial offset, resulting in a concentric ice layer.

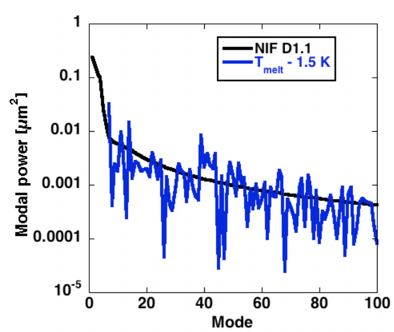


Figure 3. Plot showing the required power spectrum for NIF ice layers (black) and the measured power spectrum for a DT ice layer grown in a Be shell.

1. Bimonthly Update, March-April 2004
2. Bimonthly Update, July-August 2004

For comments about content of the ***Bimonthly Update,*** contact Bruce A. Hammel (925) 422-3299.
To get on the mailing list of the *LLNL ICF Program Bimonthly Update and Annual Report* send a request to cassady1@llnl.gov
These reports and other LLNL ICF Program information are available on our Web site at http://www.llnl.gov/nif/icf/icf.html
This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory